Pre-experimental stimulus familiarity modulates the effects of item repetition on source memory

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Abstract

Previous studies have reported contradictory findings regarding the effects of item repetition on the subsequent encoding of contextual details associated with items (i.e., source memory). Whereas some studies reported repetition-induced enhancement in source memory, other studies observed repetition-induced impairment. To resolve these conflicting results, we examined the modulatory role of pre-experimental stimulus familiarity in the relationship between item repetition and new source memory formation by orthogonally manipulating pre-experimental stimulus familiarity and intra-experimental item repetition. In a series of experiments consisting of three phases (item repetition, item-source association, and source memory test), we found that item repetition impaired source memory for pre-experimentally familiar items (famous faces or words), whereas the same manipulation improved source memory for pre-experimentally novel items (non-famous faces or pseudowords). Crucially, item repetition impaired, rather than improved, source memory for pre-experimentally novel items when these items had been pre-exposed to participants prior to the three-phase procedure. Collectively, these findings provide strong evidence that pre-experimental stimulus familiarity determines the relative costs and benefits of experimental item repetition on the encoding of new item-source associations. By demonstrating the interaction between different types of stimulus familiarity, the present findings advance our understanding of how prior experience affects the formation of new episodic memories.

Pre-experimental stimulus familiarity modulates the effects of item repetition on source memory

Episodic remembering involves the subjective experience of cohesive events consisting of various features that are bound together (Johnson & Raye, 1981; Tulving, 1983). That is, episodic remembering requires the recognition or recall of not only items but also other features (e.g., time, place, thoughts or emotion experienced) associated with them (i.e., source memory; Johnson, Hashtroudi, & Lindsay, 1993). Given that much of our daily experience involves familiar people, objects and places, understanding how prior experience with an item affects the encoding of new item-source associations is fundamental to the understanding of how memory functions in everyday contexts.

A number of previous studies (Kim, Yi, Raye, & Johnson, 2012; Poppenk, Köhler, & Moscovitch, 2010; Poppenk, McIntosh, Craik, & Moscovitch, 2010; Poppenk & Norman, 2012) investigated how prior experience with an item influences source memory, employing the following three phases: In Phase 1, items were presented a varying number of times, including no repetition. In Phase 2, the same items were presented once with a new source feature (e.g., location, task performed). In Phase 3, memory for the source previously associated with each item in Phase 2 was probed. Despite the use of the identical procedure, the findings from these studies were mixed: In some studies (Poppenk, Köhler, et al., 2010; Poppenk, McIntosh, et al., 2010; Poppenk & Norman, 2012) item repetition enhanced source memory whereas in another study (Kim et al., 2012) item repetition impaired source memory. How can these seemingly contradictory findings be reconciled? What might be the critical factor that determines the benefits vs. costs of item repetition on source memory?

Here, we propose pre-experimental stimulus familiarity as a major factor modulating the effect of item repetition on subsequent item-source associations. Close examination of the prior studies reporting contradictory results revealed that while having highly similar experimental design and procedures, they differed in terms of the stimuli they used. In studies where item repetition improved source memory, the stimuli were photographs of unfamiliar scenes with no known landmarks (Poppenk, McIntosh, et al., 2010) or foreign proverbs (Poppenk, Köhler, et al., 2010; Poppenk & Norman, 2012), which were pre-experimentally novel to participants. In contrast, line drawings of familiar everyday objects were used in the study where item repetition impaired source memory (Kim et al., 2012). On one hand, item repetition can benefit the encoding of item-source associations by allowing items to be processed more efficiently (Tulving & Schacter, 1990) and to become associated with richer semantic/contextual details that can provide scaffolding for new associations (Poppenk & Norman, 2012). Compared to novel stimuli, pre-experimentally familiar stimuli may benefit less from these repetition-induced effects**,** as they already have well-established representations and associated meanings/contexts, hence reduced potential for improvement. Indeed, repetition-induced improvements in speed and accuracy of perceptual or semantic processing have been found to be smaller for relatively more familiar or frequently encountered items (Scarborough, Cortese, & Scarborough, 1977; Stevenage & Spreadbury, 2006; but see Henson, 2003). On the other hand, item repetition can impair the encoding of item-source associations by decreasing attention or orienting responses (Ranganath & Rainer, 2003; Sokolov, 1963). These negative effects are generally greater for pre-experimentally familiar stimuli, as novel stimuli show less habituation or even enhanced orienting responses following repetition (Cycowicz & Friedman, 1998, 2007). Thus, it is possible that the costs of repetition-induced attention reduction may outweigh the benefits of repetition-induced learning for pre-experimentally familiar stimuli, whereas the benefits may outweigh the costs for unfamiliar stimuli.

To test the modulatory role of pre-experimental stimulus familiarity in the relationship between item repetition and source memory, we used the 3-phase procedure and orthogonally manipulated pre-experimental stimulus familiarity and intra-experimental item repetition. Specifically, we compared source memory for repeated vs. unrepeated items, separately for pre-experimentally familiar stimuli and their unfamiliar counterparts (famous *vs.* non-famous faces in Experiments 1, 4A and 4B; words *vs*. pseudowords in Experiment 2). We predicted that item repetition would negatively affect source memory for pre-experimentally familiar stimuli, whereas it would positively affect source memory for pre-experimentally novel stimuli. In the two follow-up experiments, instead of using pre-experimentally familiar stimuli, we *induced* stimulus familiarity by exposing pre-experimentally novel stimuli (non-famous faces in Experiment 3A; pseudowords in Experiment 3B) to participants *prior to* the main 3-phase experiment. We predicted that if pre-experimental familiarity alone can modulate the effects of item repetition on item-source associations, pre-exposure of novel stimuli prior to the experiment would produce *negative*, rather than positive, effects of item repetition on source memory.

Experiment 1

We used a 2 (pre-experimental stimulus familiarity: famous faces or non-famous faces) X 2 (item repetition: repetition or no repetition) mixed-factorial design with pre-experimental stimulus familiarity as a between-participants factor and item repetition as a within-participants factor. We expected to find an interaction between pre-experimental stimulus familiarity and item repetition in which item repetition impairs source memory for pre-experimentally familiar items (i.e., famous faces) but benefits source memory for pre-experimentally novel items (i.e., non-famous faces).

Method

Participants. Twenty-four undergraduate students participated for course credit or payment. Informed consent was obtained in accordance with procedures approved by the Departmental Review Committee of Yonsei University. Participants were randomly assigned to either the familiar (*N* = 12; 8 females; mean age = 22.8 years, *SD* =3.8 years) or unfamiliar condition (*N* = 12; 8 females; mean age = 21.8 years, *SD* = 3.5 years). One additional participant in the famous face group was removed from analysis for not responding in 87.5% of trials in the item-source association phase. All participants were native Korean speakers with normal or corrected-to-normal vision. For Experiments 1, 2, 3A and 3B, the number of participants assigned to each pre-experimental stimulus familiarity condition was determined through power analysis using effect sizes obtained from prior studies (Kim et al., 2012; Poppenk, McIntosh, et al., 2010).[1]

Materials. A total of 48 famous face images and 48 non-famous face images were obtained from various online sources. Famous face images consisted of pictures of celebrities widely known to the general public in Korea (e.g., musicians, comedians, etc.). Non-famous face images comprised of pictures of random individuals with whom the participants were not previously acquainted. Pre-experimental familiarity ratings (1 = "not familiar at all" to 5 = "very familiar") from an independent set of observers ($N = 14$; 7 rated the famous faces; 7 rated the non-famous faces) confirmed that the famous faces ($M = 4.34$, $SD = .34$) were subjectively more familiar than the non-famous faces ($M = 2.74$, $SD = .55$), $F(1, 94) = 292.48$, $p < .001$, $\eta_p^2 = .757$, 95% CI of difference = [1.41, 1.78]. For both the famous and the non-famous faces, half of the images were male faces and the other half were female faces. Separately for the famous and non-famous faces, the images of each gender were further divided into two sets of 12 images in each, resulting in two male sets and two female sets. Among the four sets, one male set and one female set (24 images in total) were assigned to the repetition condition to be presented during the item repetition phase. The remaining two sets were assigned to the no repetition condition. Repetition and no repetition face sets were counterbalanced across participants within each pre-experimental stimulus familiarity condition. All face images were cropped to show only the face and hair of the individual, converted to grayscale, and placed in the center of a 9° X 9° gray square.

Procedure. The experiment consisted of three phases as in previous studies (Kim et al., 2012; Poppenk, Köhler, et al., 2010): item repetition, item-source association, and source memory test (**Fig. 1**). Participants were informed about the source memory test in advance. In all phases, participants responded by pressing a button on a keyboard. The procedures for the famous face and non-famous face groups were identical except for the stimuli used.

Phase 1. Item repetition. Participants were exposed to the 24 faces in the repetition condition (famous or non-famous, depending on the pre-experimental stimulus familiarity condition) eight times per face. Each trial began with a 700-ms fixation, followed by a face image at the center of the screen presented for 1 s. Participants made a male/female judgment for each face. Participants completed a total of 288 trials, divided into 8 blocks of 24 trials each. Each of the 24 faces in the repetition condition was presented once within each block. The presentation order was randomized within each block. Participants were allowed to take short breaks between blocks.

Phase 2. Item-source association. Participants learned associations between face images and their location (i.e., quadrant) on the screen. Both the 24 faces presented in the item repetition

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[1] Given two-tailed tests and α level of .05, the minimum sample sizes required to achieve 80% or greater power to detect the negative (Kim et al., 2012, Experiment 1; $\eta_p^2 = .52$) and positive (Poppenk, McIntosh, et al., 2010; $d_z = .1.19$) effects of item repetition on source memory accuracy were 7 and 8, respectively.

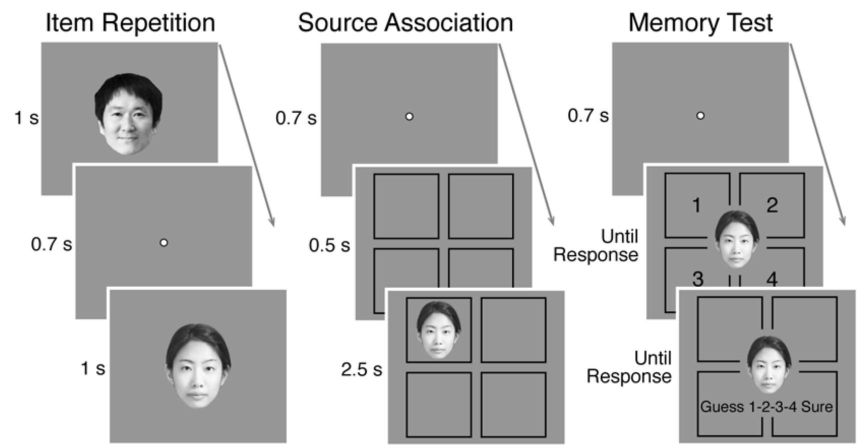

Figure 1**.** Task structure of Experiment 1.

phase and the 24 new faces assigned to the no repetition condition were presented. Each trial began with a 700-ms fixation followed by four black square frames, each presented in one of the quadrants of the screen. After 500 ms, a face image appeared inside one of the frames for 2.5 s. The location of the face image was randomly determined with the restriction that face images appeared in each quadrant equally often throughout the phase. Participants were instructed to pay attention to the location of each face while making a male/female judgment. Participants completed a total of 48 trials. Each face was presented only once and the trial order was randomized for each participant.

Phase 3. Source memory test. Participants were tested on their source memory for the locations of the 48 face images presented during the item-source association phase. Each face image was presented once in a randomized order, resulting in 48 trials. Each trial began with a 700-ms fixation, followed by a face image and four black square frames presented concurrently. Each frame was presented in one of the quadrants of the screen with a number 1, 2, 3, or 4 denoting the quadrant written inside. The face image was presented at the center of the screen on top of the frames. Participants were asked to indicate in which quadrant the face image was presented during the item-source association phase. The numbers inside the frames disappeared once the participant made a response. After 200 ms, a 4-point scale (1 = “Guessed” to 4 = “Sure”) appeared on the screen and participants rated how confident they were about their memory judgment. All trials were self-paced.

Results and Discussion

To test whether the pre-experimental familiarity of stimuli modulated the effects of item repetition on subsequent source memory, we performed a 2 (famous faces, non-famous faces) X 2 (repetition, no repetition) mixed-design analysis of variance (ANOVA) (**Fig. 2**). Source memory accuracy was defined as the percent correct location memory responses made during the source memory test phase (chance = 25%). As expected, we found a significant interaction between pre-experimental stimulus familiarity and item repetition, $F(1, 22) = 22.98$, $p < .001$, $\eta_p^2 = .511$. Specifically, in the famous face group, source memory was more accurate for unrepeated

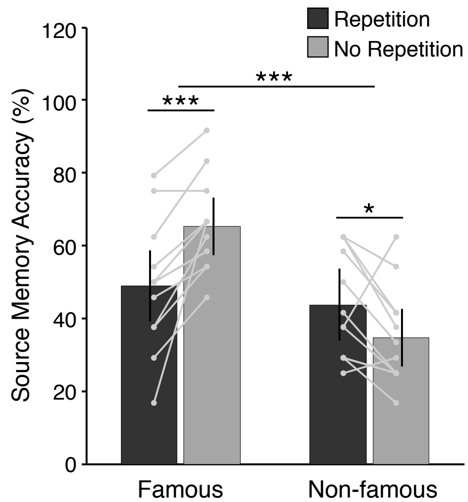

Figure 2. Source memory accuracy from Experiment 1. Gray dots represent individual participants' accuracy. Accuracies within each participant are connected with gray lines. Error bars represent 95% confidence intervals. Asterisks indicate statistical significance (***$p < .001$, *$p < .05$).

(M = 65.3%) than repeated faces (M = 49.0%), $F(1, 11) = 20.47$, $p < .001$, $\eta_p^2 = .651$, 95% CI of difference = [8.4, 24.3]. In contrast, in the non-famous face group, source memory was more accurate for repeated (M = 43.8%) than unrepeated faces (M = 34.7%), $F(1, 11) = 5.45$, $p = .04$, $\eta_p^2 = .331$, 95% CI of difference = [.5, 17.5]. There was also a significant main effect of pre-experimental stimulus familiarity in which source memory was better for famous (M = 57.1%) than non-famous faces (M = 39.2%), $F(1, 22) = 10.70$, $p = .004$, $\eta_p^2 = .327$. No overall memory difference was found between repetition and no repetition conditions, $F(1, 22) = 1.90$, $p = .182$, $\eta_p^2 = .080$.

We also found the same pattern of interaction in the average confidence ratings of all source memory responses, $F(1, 22) = 28.54$, $p < .001$, $\eta_p^2 = .565$. Post-hoc comparisons revealed that in the famous face group, confidence ratings were higher for unrepeated (M = 2.83) than repeated faces (M = 2.44), $F(1, 11) = 16.36$, $p = .002$, $\eta_p^2 = .598$, 95% CI of difference = [.18, .60]. However, in the non-famous face group, the confidence rating was higher for repeated (M = 2.63) than unrepeated faces (M = 2.08), $F(1, 11) = 13.91$, $p = .003$, $\eta_p^2 = .558$, 95% CI of difference = [.22, .86]. Neither the main effect of pre-experimental stimulus familiarity, $F(1, 22) = 2.79$, $p = .109$, $\eta_p^2 = .113$, nor the main effect of item repetition was significant, $F < 1$, $p > .38$.

To supplement the conventional ANOVAs, we additionally used mixed-effect models to analyze trial-by-trial source memory accuracy and confidence ratings. Specifically, a generalized linear mixed model with a logistic link function was used to analyze source memory accuracy. A cumulative link mixed model was used to analyze confidence ratings as an ordinal variable. In both models, we included pre-experimental stimulus familiarity, item repetition, and the interaction between them as fixed effects. As random effects, we included by-participant and by-item intercepts along with by-participant random slopes for item repetition. Likelihood ratio tests against null models including all independent variables except for the interaction replicated the ANOVA results: the interaction between pre-experimental stimulus familiarity and item repetition significantly predicted both trial-by-trial source memory accuracy, $\chi^2(1) = 16.22$, $p < .001$, and confidence ratings, $\chi^2(1) = 19.37$, $p < .001$. Together, these findings clearly demonstrate that item repetition can have opposite effects on source memory formation depending on the pre-experimental familiarity levels of stimuli.

Experiment 2

Experiment 1 demonstrated opposite effects of item repetition for pre-experimentally familiar vs. unfamiliar stimuli. However, it is possible that the famous and non-famous faces used in Experiment 1 differed not only in pre-experimental familiarity levels but also in the likelihood of verbal labeling/rehearsal. That is, participants could name the famous faces but not the non-famous faces, which might have resulted in different encoding strategies. To eliminate this potential confound and to test the generalizability of the findings, we conducted Experiment 2 using words and pseudowords, both of which were verbally rehearsable. We expected to replicate the interaction between pre-experimental stimulus familiarity and item repetition.

Method

Participants. Thirty undergraduate students were newly recruited and randomly assigned to either the word (*N* = 15; 10 females; mean age = 20.8 years, *SD* = 3.2 years) or pseudoword group (*N* = 15; 9 females; mean age = 20.7 years, *SD* = 2.5 years). One additional participant in the pseudoword group was excluded from analysis for failing to follow instructions and not responding during the item repetition phase.

Materials. Word stimuli consisted of 48 three-syllable Korean nouns denoting common objects or places (e.g. "milgaru" and "samusil," which are "flour" and "office" in Korean, respectively). Pseudoword stimuli consisted of 48 three-syllable non-words which did not have a dictionary definition. We created the pseudowords by combining three random syllables selected from the same pool of syllables of which the word stimuli were comprised (e.g. "gamumil", "silrusa"). Thus, the words and pseudowords were matched in terms of the length as well as visual and phonetic characteristics. Separately for the words and the pseudowords, the stimuli were randomly divided into four sets of 12 items each. Among the four sets, two sets (24 items) of words or pseudowords were assigned to the repetition condition. The remaining two sets were assigned to the no repetition condition. The repetition and no repetition sets were counterbalanced across participants within each pre-experimental stimulus familiarity group. Each word or pseudoword was presented in black and had the height of 2° and the length of 5°.

Procedure. The procedures of Experiment 2 were identical to those of Experiment 1, except for the stimuli used and the tasks performed during the item repetition and item-source association phases. Participants performed the preference judgment tasks during the first two phases by indicating whether they liked or did not like the word or pseudoword presented in each trial.

Results and Discussion

A two-way mixed-design ANOVA revealed that Experiment 2 successfully replicated the interaction between pre-experimental stimulus familiarity and item repetition, generalizing the findings observed in Experiment 1 to a completely different stimulus category (**Fig. 3**), $F(1, 28) = 29.38$, $p < .001$, $\eta_p^2 = .512$. In the word group, source memory accuracy was higher for unrepeated ($M = 75.6\%$) than repeated items ($M = 56.1\%$), $F(1, 14) = 28.70$, $p < .001$, $\eta_p^2 = .672$, 95% CI of difference = [11.7, 27.2]. In contrast, in the pseudoword group, source memory was marginally more accurate for repeated ($M = 52.8\%$) than unrepeated items ($M = 45.8\%$), $F(1, 14) = 4.58$, $p = .050$, $\eta_p^2 = .247$, 95% CI of difference = [-0.0, 13.9]. The main effects of pre-experimental stimulus familiarity and item repetition were both significant. Specifically, source memory accuracy was higher in the word ($M = 65.8\%$) than the pseudoword group ($M = 49.3\%$), $F(1, 28) = 11.60$, $p = .002$, $\eta_p^2 = .293$, and was higher in the no repetition ($M = 60.7\%$) than the repetition condition ($M = 54.4\%$), $F(1, 28) = 6.59$, $p = .016$, $\eta_p^2 = .191$.

Qualitatively identical results were observed in confidence ratings as well. Similar to the accuracy results, the main effect of pre-experimental stimulus familiarity was significant (words $M = 2.83$; pseudowords $M = 2.44$), $F(1, 28) = 8.40$, $p = .007$, $\eta_p^2 = .231$, and the main effect of item repetition was marginally significant (repetition $M = 2.54$; no repetition $M = 2.73$), $F(1, 28) = 3.73$, $p = .064$, $\eta_p^2 = .118$. More importantly, the effect of item repetition was significantly modulated by pre-experimental stimulus familiarity, $F(1, 28) = 30.61$, $p < .001$, $\eta_p^2 = .522$. In the word group, the participants were more confident on their source memory for unrepeated ($M = 3.18$) than repeated items ($M = 2.47$), $F(1, 14) = 25.85$, $p < .001$, $\eta_p^2 = .649$, 95% CI of difference = [.41, 1.01]. In contrast, in the pseudoword group, the participants' confidence ratings were higher for repeated ($M = 2.61$) than unrepeated items ($M = 2.27$), $F(1, 14) = 7.03$, $p = .019$, $\eta_p^2 = .334$, 95% CI of difference = [.07, .62].

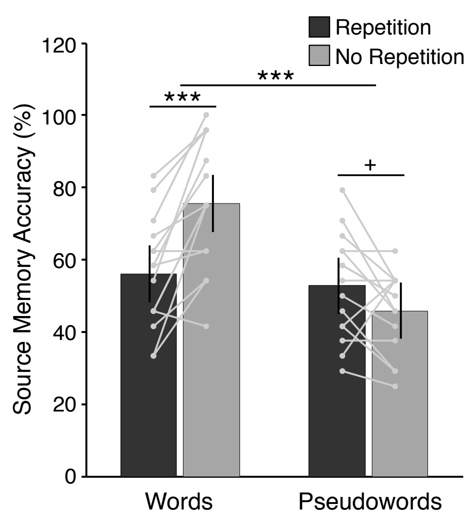

Figure 3. Source memory accuracy from Experiment 2. Gray dots represent individual participants' accuracy. Within-participant accuracies are connected with a gray line. Error bars represent 95% confidence intervals. Asterisks and the cross symbol indicate statistical significance (***$p < .001$, +$p < .06$).

We also analyzed trial-by-trial source memory outcomes and confidence ratings using the same mixed-effects modeling approach as in Experiment 1. Again, the interaction between pre-experimental stimulus familiarity and item repetition significantly predicted both source memory accuracy, $\chi^2(1) = 22.42$, $p < .001$, and confidence ratings, $\chi^2(1) = 22.43$, $p < .001$. Collectively, these results provide evidence against the possibility that variables other than pre-experimental experience with a stimulus, such as verbal labeling or perceptual characteristics specific to the famous and non-famous faces, modulated the effects of item repetition in Experiment 1.

Experiments 3A & 3B

In these experiments, we sought to further confirm that prior experience with a stimulus was the critical factor that modulated the effects of item repetition on source memory. Specifically, we tested whether item repetition would reverse its effects on source memory for pre-experimentally novel stimuli from positive to negative when participants had a chance to experience these stimuli prior to the experiment (i.e., pre-experimentally *induced* familiarity). For Experiments 3A and 3B, we used the same non-famous faces and pseudowords used in Experiments 1 and 2, respectively. All procedures were identical to Experiments 1 and 2, except that all stimuli were pre-exposed to participants a day before the 3-phase main experiment. We predicted that item repetition would *impair* rather than enhance source memory for the non-famous faces and pseudowords once they become pre-experimentally familiar.

Method

Participants. Thirteen undergraduate students participated in Experiment 3A (9 females; mean age = 21.6 years, *SD* = 1.9 years). Another thirteen undergraduate students participated in Experiment 3B (3 females; mean age = 22.6 years, *SD* = 2.9 years).

Materials. For Experiment 3A, we used the same 48 non-famous face images used in Experiment 1. In Experiment 3B, the same 48 pseudowords presented in Experiment 2 were used. The stimuli for Experiments 3A and 3B were assigned to the repetition and no repetition conditions in the same way as in Experiments 1 and 2, respectively. In both experiments, identical sets of stimuli were presented on Day 1 and Day 2.

Procedure. Both Experiments 3A and 3B were conducted on two consecutive days. The procedures of the two experiments were identical except for the stimuli used and the tasks performed during the item repetition and item-source association phases on Day 2 (i.e., male/female judgment in Experiment 3A and preference judgment in Experiment 3B).

Day 1. Participants were pre-familiarized with 48 non-famous faces (Experiment 3A) or 48 pseudowords (Experiment 3B). Participants completed a total of 1440 trials, divided into 10 blocks of 144 trials each. Each item was repeated three times within a block. Thus, participants were exposed to each item 30 times in total, except for two participants in Experiment 3B whose sessions were terminated in the ninth block due to a technical issue. These two participants were exposed to each item 24 to 27 times. The presentation order was randomized within each block. Each trial began with a 250-ms fixation, followed by a face or pseudoword stimulus presented for 1 s at the center of the screen. Participants indicated whether it was the first, second, or third time the given item was presented within the block. In order to make correct responses, participants had to pay close attention to the identity of each item in every trial. At the end of each block, performance feedback on the accuracy of the block was provided. Participants were allowed to have short breaks between blocks.

Day 2. The Day 2 procedures of Experiments 3A and 3B were identical to the three-phase procedures in Experiments 1 and 2, respectively.

Results and Discussion

Overall accuracy of the pre-exposure task during Day 1 was 61.1% (*SD* = 6.2%) and 58.6% (*SD* = 8.3%) in Experiments 3A and 3B, respectively (chance = 33.3%). To test the effect of item repetition on subsequent source memory formation during Day 2, we performed one-way repeated-measures ANOVAs separately for Experiments 3A and 3B. As expected, item repetition negatively affected source memory in both experiments even though we used the same non-famous faces and pseudowords used in Experiments 1 and 2 (**Fig. 4**): in Experiment 3A, source memory accuracy was higher for unrepeated (M = 65.1%) than repeated faces (M = 54.2%), $F(1, 12) = 7.78$, $p = .016$, $\eta_p^2 = .394$, 95% CI of difference = [2.4, 19.4]. Confidence ratings were also higher for unrepeated (M = 2.81) than repeated faces (M = 2.55), $F(1, 12) = 5.77$, $p = .033$, $\eta_p^2 = .325$, 95% CI of difference = [.02, .5]. Likewise, in Experiment 3B, source memory accuracy was higher for unrepeated (M = 49.4%) than repeated pseudowords (M = 40.4%), $F(1, 12) = 5.11$, $p = .043$, $\eta_p^2 = .299$, 95% CI of difference = [.3, 17.6], although no significant difference was found in confidence ratings (repetition M = 2.49, no repetition M = 2.49), $F < 1$, $p > .9$.

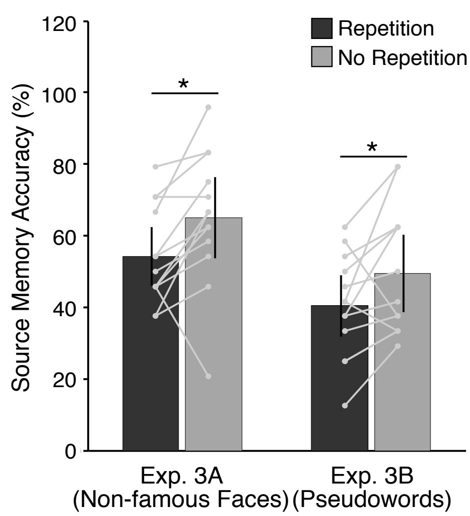

Figure 4. Source memory accuracy from Experiments 3A and 3B. Gray dots represent individual participants' accuracy. Within-participant accuracies are connected with a gray line. Error bars represent 95% confidence intervals. Asterisks indicate statistical significance (*$p < .05$).

In the mixed-effects analysis of trial-by-trial source memory accuracy and confidence ratings, we included item repetition as a single fixed effect. For random effects, we included by-participant and by-item intercepts along with by-participant random slopes for item repetition. Again, the results closely mirrored those from the ANOVAs. Item repetition predicted incorrect source memory in both Experiment 3A, $\chi^2(1) = 6.49$, $p = .01$, and Experiment 3B, $\chi^2(1) = 4.37$, $p = .04$. Item repetition also predicted lower confidence ratings in Experiment 3A, $\chi^2(1) = 7.07$, $p = .008$, but not in Experiment 3B, $\chi^2(1) = .01$, $p = .92$.

Overall, in both Experiments 3A and 3B, we were able to reverse the effect of item repetition on source memory for previously unfamiliar stimuli from positive (shown in Experiments 1 and 2) to negative by familiarizing participants with the stimuli in advance, providing further evidence that prior experience with a stimulus modulates the item repetition effects.

Experiments 4A & 4B

Experiments 1-3 consistently demonstrated that the effects of item repetition on source memory were modulated by pre-experimental stimulus familiarity. However, one might claim that our findings were driven by confounds specific to the experimental design and procedures we adopted. For example, in all above experiments, the cover tasks (i.e., male/female judgment for faces, like/dislike judgment for words) were identical between the item repetition and item-source association phases. Thus, the effects of item repetition on item-source associations might have been influenced by the learning of task-specific behavioral responses rather than item representations per se. In addition, as pre-experimental stimulus familiarity was a between-subjects variable, an item was always presented between items from the same pre-experimental stimulus familiarity condition. Thus, there is a possibility that pre-experimental stimulus familiarity of nearby items as well as that of the target item affected source encoding. To address these potential confounds and increase generalizability of our findings, we conducted two additional follow-up experiments using face stimuli. We used procedures modified from those of Experiments 1 and 2. In Experiment 4A, we used different tasks for the item repetition and item-source association phases to remove potential effects of repetition-induced response learning on source encoding. In Experiment 4B, pre-experimental stimulus familiarity was manipulated within-subjects such that pre-experimentally familiar and novel stimuli were randomly interleaved in all experimental phases. We expected to replicate the interaction between pre-experimental stimulus familiarity and item repetition in both experiments, regardless of the changes made to the experimental procedures.

Method

Participants. A total of 48 undergraduate students participated in Experiment 4A and were randomly assigned to either the famous face ($N = 24$; 12 females; mean age = 24.3 years, $SD = 2.4$ years) or non-famous face group ($N = 24$; 12 females; mean age = 23.9 years, $SD = 1.6$ years). One additional participant in the non-famous face group was excluded from analysis for not responding in two-thirds of the trials during the item-source association phase. Another 28 undergraduate students participated in Experiment 4B (14 females; mean age = 24.3 years, *SD* = 2.7 years). The sample size of Experiments 4A and 4B was determined through power analysis using effects sizes (η_p^2) obtained from Experiments 1 and 2. We estimated that the sample size per pre-experimental stimulus familiarity condition should be at least between 19 (Experiment 1) and 27 (Experiment 2) to achieve 80% or greater power to detect the effect of item repetition on source memory accuracy in both pre-experimentally familiar and novel stimuli, given two-tailed tests and α level of .05.

Materials. In Experiment 4A, 48 famous face images and 48 non-famous face images were used. In Experiment 4B, 40 famous face images and 40 non-famous face images were used. In both experiments, half of the famous faces were females and the other half were males. Likewise, half of the non-famous faces were females and the other half were males. The images were randomly assigned to the repetition and no repetition conditions for each participant with the restriction that the numbers of female and male faces were balanced within each condition.

Procedure. The procedure of Experiment 4A was identical to that of Experiment 1 except that participants performed a location judgment task (vs. male/female judgement in Experiment 1) during the item-source association phase. Specifically, participants were asked to indicate in which quadrant the face image was presented by pressing one of four buttons (1, 2, 3, and 4). The procedure of Experiment 4B was largely identical to that of Experiment 4A except that the famous and non-famous face conditions were manipulated within-subjects. In all phases, famous faces were presented in half of the trials and non-famous faces were presented in the other half. The order of famous and non-famous face trials within each phase was randomized for each participant. The number of trials was 40 per block (320 trials in total) in the item repetition phase, 80 in the item-source association phase, and 80 in the source memory test phase. As participants studied a larger number of faces than in Experiment 4A, we increased the duration of inter-trial fixation (1 s) and face image presentation (3.5 s) in the item-source association phase to aid participants in encoding the face-location associations.

Results and Discussion

Two-way mixed-model and repeated-measures ANOVAs revealed that the interaction between pre-experimental stimulus familiarity and item repetition on source memory accuracy was replicated in both Experiment 4A, $F(1, 46) = 30.87$, $p < .001$, $\eta_p^2 = .402$, and Experiment 4B, $F(1, 27) = 7.47$, $p = .011$, $\eta_p^2 = .217$. In Experiment 4A, source memory accuracy was higher for unrepeated ($M = 70.14\%$) than repeated famous faces ($M = 56.60\%$), $F(1, 23) = 18.78$, $p < .001$, $\eta_p^2 = .45$, 95% CI of difference = [7.1, 20.0]. In contrast, source memory accuracy was higher for repeated ($M = 57.47\%$) than unrepeated ($M = 45.66\%$) non-famous faces, $F(1, 23) = 12.61$, $p = .002$, $\eta_p^2 = .354$, 95% CI of difference = [4.9, 18.7]. Likewise, in Experiment 4B, the effect of item repetition was negative for famous faces (unrepeated $M = 67.86\%$; repeated $M = 61.25\%$), $F(1, 27) = 6.22$, $p = .019$, $\eta_p^2 = .187$, 95% CI of difference = [1.2, 12.0], whereas the effect was marginally positive for non-famous faces (unrepeated $M = 40.36\%$; repeated $M = 45.89\%$), $F(1, 27) = 2.96$, $p = .097$, $\eta_p^2 = .099$, 95% CI of difference = [-1.1, 12.1]. Source memory accuracy was overall higher for famous than non-famous faces in both experiments, $F_s > 7.5$, $p_s < .009$.

The main effect of item repetition was not significant in either experiment, $F_s < 1$, $p_s > .7$.

Confidence ratings showed the same pattern of interaction between pre-experimental stimulus familiarity and item repetition in both Experiment 4A, $F(1, 46) = 44.88$, $p < .001$, $\eta_p^2 = .494$, and Experiment 4B, $F(1, 27) = 29.37$, $p < .001$, $\eta_p^2 = .521$. In Experiment 4A, item repetition decreased confidence for famous faces (unrepeated $M = 2.94$; repeated $M = 2.69$), $F(1, 23) = 10.31$, $p = .004$, $\eta_p^2 = .31$, 95% CI of difference = [.09, .42], while it increased confidence for non-famous faces (unrepeated $M = 2.13$; repeated $M = 2.81$), $F(1, 23) = 35.13$, $p < .001$, $\eta_p^2 = .604$, 95% CI of difference = [.44, .91]. Similarly, in Experiment 4B, item repetition decreased confidence for famous faces (unrepeated $M = 3.07$; repeated $M = 2.89$), $F(1, 27) = 6.27$, $p = .019$, $\eta_p^2 = .189$, 95% CI of difference = [.03, .32], whereas it increased confidence for non-famous faces (unrepeated $M = 2.00$; repeated $M = 2.43$), $F(1, 27) = 34.99$, $p < .001$, $\eta_p^2 = .564$, 95% CI of difference = [.28, .58]. The main effects of pre-experimental familiarity and item repetition were also significant in both experiments, $F_s > 6.58$, $p_s < .02$, showing that confidence ratings were overall higher for famous than non-famous faces and also higher for repeated than unrepeated faces.

Mixed-effects analysis further replicated the interaction between pre-experimental stimulus familiarity and item repetition on source memory accuracy in both Experiment 4A, $\chi^2(1) = 25.11$, $p < .001$, and Experiment 4B, $\chi^2(1) = 5.92$, $p = .01$. Again, qualitatively identical interactions were observed in confidence ratings in Experiments 4A, $\chi^2(1) = 32.79$, $p < .001$, and 4B, $\chi^2(1) = 22.56$, $p < .001$. Together, Experiments 4A and 4B successfully replicated and generalized our findings from Experiments 1 and 2, suggesting that the modulatory effects of pre-experimental familiarity were not driven by confounds specific to the experimental procedures we used.

General Discussion

By orthogonally manipulating pre-experimental stimulus familiarity and intra-experimental item repetition, we tested the modulatory effects of pre-experimental stimulus familiarity on the relationship between item repetition and source memory. Consistent across different stimulus categories (famous/non-famous faces in Experiment 1 and words/pseudowords in Experiment 2), item repetition enhanced source memory for pre-experimentally novel stimuli but impaired source memory for pre-experimentally familiar stimuli. This pattern was also consistent regardless of the specific task performed during source encoding (Experiments 4A) or whether pre-experimental stimulus familiarity was manipulated within- or between-subjects (Experiment 4B). Crucially, item repetition *negatively* rather than positively affected source memory for pre-experimentally novel stimuli (the same non-famous faces and pseudowords used in Experiments 1 and 2) when these stimuli had been exposed to participants prior to the experiment (Experiments 3A and 3B). Collectively, these findings provide strong evidence that pre-experimental stimulus familiarity critically modulates the effects of item repetition on source memory, thereby identifying an important factor that can help explain previous contradictory findings (Kim et al., 2012; Poppenk, Köhler, et al., 2010; Poppenk, McIntosh, et al., 2010;

Poppenk & Norman, 2012; see also Reggev, Sharoni, & Maril, 2018).

What might be the mechanisms underlying the benefits vs. costs of item repetition on source memory for pre-experimentally novel vs. familiar stimuli? First, the benefits of item repetition on source memory are likely attributable to the learning of items whose representations have not been fully established. Specifically, repetition-induced learning of an item can help bind lower-level features constituting the item to form a ‘unitized chunk,’ which in turn can become associated with source features or other high-level representations (Reder, Paynter, Diana, Ngiam, & Dickison, 2007). The formation of unitized item representations can also help reduce the amount of mental resources needed to process the items themselves, thereby leaving more resources available to process item-source associations (Diana & Reder, 2006; Reder, Liu, Keinath, & Popov, 2016; Reder et al., 2013). In addition, repetition provides opportunities for item representations to become associated with various internally-generated or externally-provided information, which can provide a scaffold that new source information can more easily bind onto (Poppenk & Norman, 2012). These mechanisms are not mutually exclusive, and would together or independently result in more distinctive or meaningful item representations to promote encoding of new episodic memories.

In comparison, the costs of item repetition on source memory might arise from the reduced amount of attention allocated to familiar, well-learned items, which can negatively affect the likelihood that item-source combinations will be successfully encoded. This possibility is consistent with the theoretical view that novel information has more adaptive significance than already known information and thus is prioritized at encoding (novelty-encoding hypothesis; (Tulving & Kroll, 1995; Tulving, Markowitsch, Craik, Habib, & Houle, 1996) as evidenced by the involvement of novelty-related dopaminergic signals in successful memory formation (Kamiński et al., 2018; Lisman, Grace, & Duzel, 2011). Alternatively, item repetition might induce interference due to contextual competition (Reder et al., 2007, 2013), as repeated items have a chance to form additional associations with sources presented during item repetition. This interference would be greater for pre-experimentally familiar items whose representations are already established and thus can bind with the competing sources more easily. Notwithstanding the foregoing, a previous study (Kim et al., 2012, Experiment 3) demonstrated the costs of item repetition on source memory even when the competition between the sources associated during the item repetition and item-source association phases was minimized by using two different salient source dimensions across phases (location and background color for the item repetition and item-source association phases, respectively). In addition, the same study (Kim et al., 2012, Experiment 6) suggested that the locus of the costs of item repetition is encoding rather than retrieval by showing that item repetition negatively affected source memory when the items were repeated before but not after the encoding of critical item-source associations. Thus, the interference account, though viable, may not fully account for the costs of item-repetition on source memory for pre-experimentally familiar stimuli.

Traditionally, the effects of prior experience on memory have been studied in relation to the beneficial effects of well-structured semantic knowledge or schema acquired from life-long experiences (Bird, Davies, Ward, & Burgess, 2011; Chase & Simon, 1973; Dobbins & Kroll, 2005). Our findings of overall better source memory for famous faces and words than for non-famous faces and pseudowords (Experiments 1 and 2) well coincide with these earlier works. Nevertheless, of note, the positive-to-negative reversal of the item repetition effects on source memory for initially pre-experimentally novel items occurred following only 30 repetitions of the items a day prior to the 3-phase main experiment (Experiment 3). This finding suggests that prior experience does not necessarily need to involve massive prior knowledge resulting from life-long experiences for it to affect the relationship between subsequent item repetition and new item-source associations. Rather, what appears critical is whether a prior experience with an item entailed the establishment of a distinctive unitized representation of the item (Hayes-Roth, 1977; Reder et al., 2007). This account is relevant to the discussion of whether pre-experimentally familiarized and intra-experimentally repeated items are qualitatively the same or different in terms of cognitive processes they engage. One possibility is that pre- and intra-experimentally familiarized items undergo qualitatively different processing if experimental repetitions did not produce fully unitized item representations. In line with this possibility, previous studies comparing novel items that were intra-experimentally repeated a small number of times (e.g., foreign proverbs repeated for 3 times, non-famous faces presented once) and pre-experimentally familiar items (e.g., previously known proverbs, famous faces) showed that different sets of brain regions are activated for the two stimulus types both during encoding (Poppenk, McIntosh, & Moscovitch, 2016) and retrieval (Gimbel, Brewer, & Maril, 2017). Further support for this possibility may come from future studies comparing cognitive/neural processes engaged by pre-experimentally familiarized items and those engaged by novel items with varying numbers of prior experimental repetitions. Additionally, given that in the present study the pre-exposure of novel items occurred a day before the experiment, future studies may examine whether sleep-induced memory consolidation/differentiation (Antony, Ferreira, Norman, & Wimber, 2017; Diekelmann & Born, 2010) is necessary for intra-experimental item repetition to reverse its effects on source memory for pre-experimentally novel items.

It needs to be mentioned that the present study used only one type of source feature (i.e., an item's location on the screen). Yet, an item is often (if not always) associated with multiple source features, and accordingly several schemes have been proposed for categorizing the variety of source features. For instance, distinctions have been made between source features that are internally-generated (e.g., a word spoken or imagined by oneself) vs. externally-generated (e.g., a word spoken by an experimenter) (Johnson et al., 1993), or between those that are intrinsic ("intra-item" attributes: e.g., shape, color) vs. extrinsic ("extra-item" attributes: e.g., background color, location, temporal sequence, task performed on an item) to an item (Geiselman & Bjork, 1980; Moscovitch, 1992; Spencer & Raz, 1995; Smith, Glenberg, & Bjork, 1978). Given different behavioral and neural correlates of memory for different types of source features (e.g., internally- vs. externally-generated: Raye, Johnson, & Taylor, 1980; Turner, Simons, Gilbert, Frith, & Burgess, 2008; intrinsic vs. extrinsic: Ecker, Zimmer, & Groh-Bordin, 2007a; 2007b; Spencer & Raz, 1995; Troyer, Winocur, Craik, & Moscovitch, 1999) as well as the relative independence of different source features (i.e., no "all-or-none" retrieval; Dodson, Holland, & Shimamura, 1998; Meiser & Bröder, 2002; Starns & Hicks, 2005; but see Starns & Hicks, 2008), replication of the present findings using different types of source features is desirable to provide further evidence for the differential mnemonic consequences of item repetition on source memory for pre-experimentally familiar vs. novel items.

To conclude, the current study identified a major factor determining the effects of item repetition on the formation of new episodic memory: pre-experimental learning of the items. Bearing significance to many studies on experience-induced learning, memory, and perception, the present findings emphasize a need for a more comprehensive approach when investigating how prior experience influences information processing--all prior experiences including those obtained outside the experimental settings can affect the consequences of learning. A fuller understanding of how prior experience influences new episodic learning awaits further research on the precise mechanisms underlying the interaction between different types of prior experience.

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